His conclusions were frequently hasty and ill founded. Lavoisier's work requires no praise in this place. Priestley's discoveries may be compared to the mingled chaos of ὁμοιομερεῖαι of Anaxagoras; Lavoisier was the Νοῦς, the designing intelligence which set them in order, and put each in its appointed place. Not without reason, said M. Wurtz, "La Chimie est une science française. Elle fut instituée par Lavoisier d'immortelle mémoire."

G. F. RODWELL

A NEW DREDGING IMPLEMENT

HAVING recently visited Oban, in company with a friend for the express purpose of obtaining living specimens of Pennatulida, and of testing the powers of an instrument devised for their capture, I send you a note of our experiences which may perhaps be of interest to your readers.

The ordinary dredge, though well adapted to obtaining most animals that dwell on the sea-bottom, will clearly not do for all, and for no animal form is it less suited than for the one we were most anxious to obtain—*Funiculina quadrangularis.* This giant Pennatulid consists of a tall fleshy rod-like axis, three to five feet or more in length, and about half an inch in diameter, which bears along its sides the individual polypes of the colony, and is traversed throughout its entire length by a flexible calcified stem. *Funiculina* lives erect, with the lowermost six or eight inches planted as a stalk in the mud of the sea-bottom, and the major portion of its length projecting up freely into the water.

For such a form the dredge is clearly very unsuitable. Indeed unless the dredge be of very great size it must be a pure accident if specimens ever get into it at all. The tangles give a better chance, and yet for such a purpose they are but a clumsy and haphazard contrivance; and even should they by chance entangle and draw out a *Funiculina* there is a danger, amounting almost to certainty that it will drop off again during the process of hauling in.

The instrument we employed was a modification of one originally devised by Dr. Malm of Göteborg, and used by him with considerable success in dredging for *Funiculina* in Gullmarn Fiord, Bohuslän. Dr. Malm's apparatus, of which he has kindly furnished us with a description and drawings, consisted of three poles, each nine feet long, connected together at their ends, so as to form a triangle; the poles were armed with large-sized fish-hooks, and the dredging-rope attached at one angle, the whole apparatus strongly resembling that used by the Philippine Islanders for dredging *Euplectella,* as described and figured by Moseley (Naturalist on the *Challenger*, p. 407).

Our instrument, as we first used it, consisted of two poles six feet long, connected together in the form of a letter A by a cross-bar four feet long. The rope was fastened to the apex of the A, and lead weights to the lower ends of the side poles. Attached along the cross-bar at intervals of six inches were cords four feet in length, each armed with five or six fish-hooks and having a small lead weight tied to its lower end. The theory of the machine was that the whole instrument would be dragged along at an angle of about 30° to the sea-bottom, steadied by the weights at the ends of the side poles; the cross-bar being a foot or so above the ground, and the cords armed with fish-hooks trailing behind, with their ends kept on the bottom by the small weights attached to them.

The machine was subsequently modified by lengthening the cross-bar to nine feet, and attaching the fish-hooks not singly, but in threes, like grappling irons. We also connected the cords together by horizontal strings, in order to obviate their tendency to become entangled with one another.

The instrument yielded excellent results: a large number of specimens of *Funiculina quadrangularis* were obtained, four or five, and in one case as many as seven being brought up at a single haul; the specimens were also in perfect condition, the injury inflicted by the hook being quite imperceptible. Several of the specimens were of large size; and one dredged in Ardmucknish Bay, and measuring no less than sixty-five inches in length, appears to be the largest specimen hitherto obtained alive from any locality, being a foot longer than the largest recorded by Kölliker in his monograph on the the Pennatulida. Even this, however, does not appear to be the limit of growth, for a dead stem obtained at Glaesvae, in the Bergen Fiord, and now in the Hamburg Museum, is more than seven feet in length.

Funiculina quadrangularis is generally considered a rare species. It is certainly a very local one; but our Oban experience would lead us to infer that where it does occur it is to be found in quantity, an inference borne out by Sir Wyville Thomson, who speaks of passing over a "forest of *Funiculina*" when dredging in Raasay Sound during the *Porcupine* expedition. It appears to have been hitherto obtained at Oban only in small numbers, a result we believe to be due entirely to the use of instruments ill-adapted to its capture.

Four or five specimens of *Pennatula phosphorea* were obtained with the same instrument, which further proved its utility by bringing up several fine specimens of Hydrozoa. The instrument in its present form is clearly capable of improvement; still the results of a first trial have been so good, that we may possibly be rendering a service to other naturalists by making them known through your columns.

A. MILNES MARSHALL

Owens College, October 27

WIRE GUNS

IT will no doubt surprise many of our readers to be told that after nearly a quarter of a century of experiment and investigation, and the expenditure of millions upon millions of money, the nation is so imperfectly armed that we are again entering upon a period of reconstruction of our heavy ordnance, the outcome of which it is not easy to foresee. From the old cast-iron 68 pounder, weighing from 4 to 5 tons, we have arrived at the 80 ton gun of Woolwich, but only to learn that such guns are already obsolete, and must give place to others of a new type developing greater power with less weight. Till very recently we have been constantly told by the highest authorities in this department of the Government that the English guns were the finest, the strongest, and the most powerful in the world, and it is no doubt somewhat startling to learn that all this has been a delusion.

It is not our intention to dwell upon the causes of this, nor to inquire whether it has been due to departmental conservatism or to the uncertainty incidental to the progress of an art carried on by a tentative method, and modified from time to time by new discoveries in physical science. Our purpose is rather to give some information about a system of gun making, which is at last obtaining the attention of gunmakers, we allude to what is termed the wire system of construction.

Twenty-seven years ago this system was brought before the then existing Ordnance Committee by the writer who has from that time to this persistently advocated its merits, proving, not only by the construction of guns but also by mathematical analysis, its great advantage over other systems; but it is only within the last two or three years that it has been regarded with tolerance by practical gun makers.

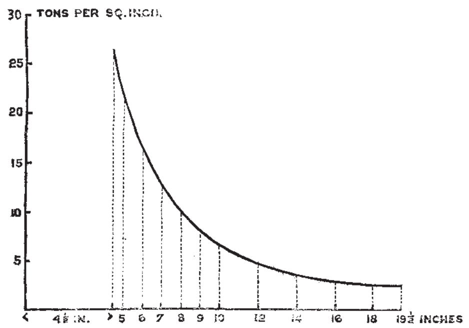
In France the system has been applied under the superintendence of Capt. Schultz, of the École Polytechnique, and in this country Sir Wm. Armstrong and Co. have made one or two guns, the latest and largest of

which is now under trial at Woolwich. So far as these guns have been tried they have given very exceptionally good results, both in France and England, and they promise to excel all others in strength, facility of construction, and economy as regards cost. Let us then attempt to explain in a popular manner the principles and methods of this system of construction.

A gun is a machine the object of which is to send heavy bodies to a great distance at a very high velocity. The motive power acts on the body for a very short time, a fraction of a second only, it must therefore be of great intensity, and consequently the machine must have very great strength. Formerly all guns were made of cast-iron or bronze; after this wrought iron and steel came into use or a combination of the two, Krupp and Whitworth adopted steel, Armstrong and Woolwich a combination of wrought-iron and steel, Palliser again, a combination of cast and wrought-iron.

In making a vessel to resist great internal pressure, it was natural to conclude that by increasing the thickness of the vessel, its resisting strength could be proportionately increased, but as was first pointed out by the late Prof. Barlow, it was found that the limit in this direction was very soon reached, and that no vessel, whatever the thickness, could resist an internal pressure greater than the tensile strength of the material of which it was made.

If the cylinder be composed of a material whose tensile strength is 10 tons per square inch, and if the internal pressure be 10 tons per square inch, and if the cylinder be conceived as to be divided into a great number of



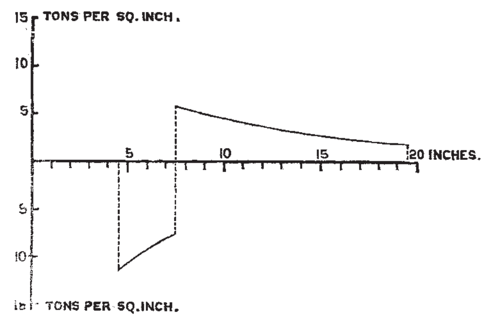
A

successive indefinitely thin layers, then, whatever be its thickness, the first of these layers will be strained to 10 tons, its maximum strength, the next layer will be strained less, and the strains will go on decreasing according to a fixed law as we proceed outwards. Now these outer layers cannot exert any more force, except it be transmitted from the innermost one, and consequently any further assistance can only be got from them by increasing the strain of the innermost layer, which, being already strained to its maximum strength, must necessarily give way.

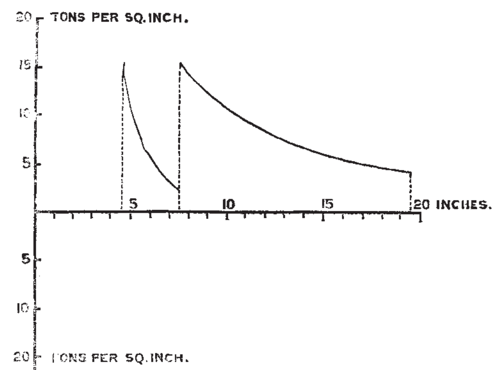
In order to meet this radical defect in all homogeneous cylinders the principle of initial tension was adopted. This was done by building up the cylinder of several concentric rings, or hoops, each of which was put on the one below it with an initial strain, thus compressing all those below. If now, by this method, the innermost hoop or tube be put into a state of compression of, say, 5 tons per square inch, it is evident that the first thing the internal pressure has to do, is to remove this compression to zero. This will absorb 5 tons per square inch of pressure. It has then to overcome the tensile strength of the material, or 10 tons per square inch, which requires an additional pressure of 10 tons per square inch. Thus the resisting force of the cylinder has been increased from 10 to 15 tons per square inch.

Now the greater the number of the hoops in a given thickness of cylinder, the greater is the additional strength imparted, *provided that each hoop is put on with the proper initial strain*, and if the hoops were infinite in number and therefore infinitely small in thickness, we could obtain the maximum strength for the thickness of cylinder, and each ring would, at the moment of rupture, be strained to its maximum tensile force. In such a cylinder the strength would increase in the exact ratio of the increase of thickness, and when it burst every layer would give way at the same time, but as there is no limit to the possible increase of thickness, there is also no limit to the possible increase of the internal pressure. Of course this theoretical construction is practically impossible, but we can approach to it very closely by making the hoops very numerous and very thin. The limit of the number of hoops is however very soon reached in the system of hoop construction.

Sir Wm. Armstrong's 100-ton gun is built up of a steel tube and three wrought-iron hoops on it. The Woolwich 81-ton gun has a steel tube and two wrought-iron hoops. Sir Wm. Armstrong's gun is therefore a better gun than



B1



B2

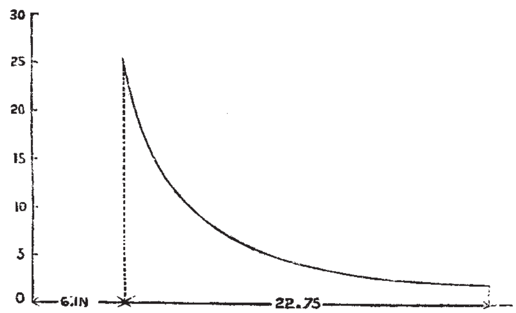
the Woolwich, assuming in both cases that the initial tensions are correctly adjusted, but if in either case the number of hoops had been doubled, the total thickness remaining the same, both guns would have been greatly increased in strength. The practical difficulties of increasing the number of rings are, however, very great, and the expense would be enormous. The proper initial tension, or *shrinkage* as it is called, depending on extreme accuracy of workmanship, would be extremely difficult of attainment, and Sir Wm. Armstrong has probably gone nearly as far as is practically possible in this direction.

The regulation of the initial tension in guns of the hoop construction is so important that it is necessary to go somewhat more into detail, in order that our readers may thoroughly understand its importance, and be in a position to appreciate the advantages attendant on the use of wire.

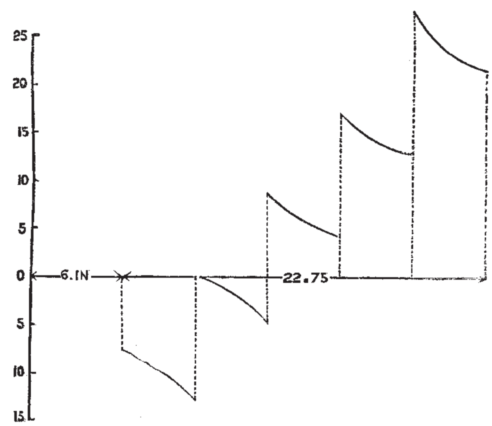
We therefore introduce to their notice a series of diagrams showing the distribution of the strains throughout the thickness of a gun. The first is the case of a

homogeneous gun, such for instance as a solid cast-steel gun as formerly made by Krupp, and we will assume it to be 9 inches calibre, and 15 inches thick at the breech end, and that it is subjected to an internal pressure of 24 tons per square inch. Now it is evident that the total strain to be resisted is 9 times 24 tons, or 216 tons, one half of which, or 108 tons must be borne by each side of the gun, or by a thickness of 15 inches of steel. If therefore the strain could be uniformly distributed, it would not exceed $\frac{108}{15}$, or 7·2 tons per square inch, but in reality the strain at the inside circumference would be nearly 27 tons per square inch, whilst at the exterior of the gun it would be only $2\frac{1}{2}$ tons per square inch.

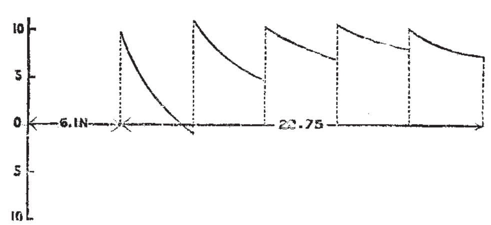
The subjoined diagram (A) represents the condition of



C₁



C₂



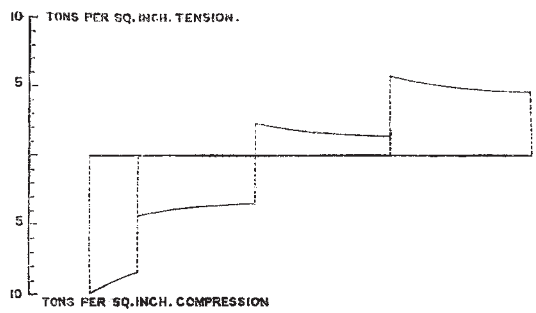
C₃

strain of such a gun under these circumstances. The abscissæ denote the distances from the centre of the bore, whilst the corresponding ordinates denote the strains in tons per square inch at these distances.

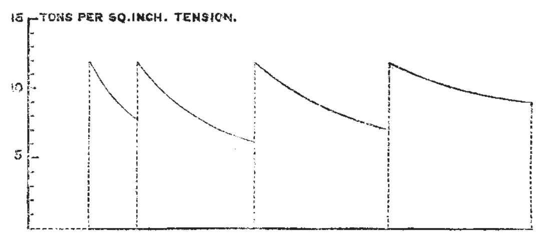
In the next place let us examine the condition of strain of a gun of the same calibre, but composed of an internal steel tube $3\frac{1}{8}$ inches thick upon which is shrunk a wrought-iron hoop $12\frac{7}{8}$ inches thick with a shrinking of 1 in a thousand. This was the Woolwich construction for all guns up to 9-inch calibre up to 1869.

Subjected to an internal pressure of 24 tons per square inch, the diagram B_2 shows the induced strains. Previous to the internal pressure being applied, diagram B_1 shows that the steel tube would be compressed by the outer wrought-iron hoop. The compression would be 11·7 tons per square inch at the inner and 7·86 tons at the outer circumference; on the other hand the wrought-iron hoop would be in a state of tension, 5·19 tons per square inch at the inner and 1·38 tons at the outer circumference. When the internal pressure of 24 tons per square inch is applied, the diagram B_2 shows the condition of strain. The steel tube would be strained to 15·53 tons per square inch at the inner, but only to 2·67 tons at the outer circumference, whilst for the wrought iron hoop the strains would be 15·09 and 4 tons respectively per square inch. Thus it appears that comparing this gun with the homogeneous gun of the same size and under the same conditions the maximum strain has been reduced from 27 tons to 15·83 tons per square inch.

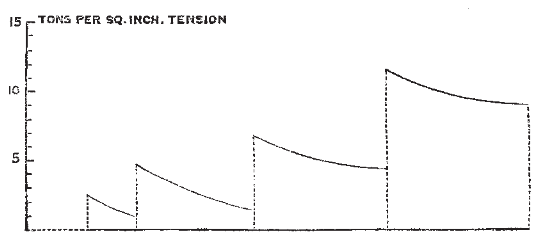
Pursuing the matter further let us examine the conditions of Sir Joseph Whitworth's 12-inch gun, built up of a steel tube 4·35 inches thick, on which are placed four successive steel hoops, each of 5·55 inches thick, the



D₁



D₂



D₃

total thickness of the gun being thus $22\frac{1}{2}$ inches. Before proceeding to the examination of the strains in this gun, it is desirable to devote a moment or two to the very important question of the amount of initial strains with which hoops should be put on. The Woolwich practice is to adopt a uniform shrinkage of 1 in a 1000, that is to say, the internal diameter of each hoop is 999/1000ths of the external diameter of the hoop below it. The outer hoop is expanded by heat, placed over the inner one, and then in cooling grips it with the force due to a contraction of 1/1000th of its size. This is a fundamental error in the Woolwich practice, and it is mainly from their persistence in this error that so many Woolwich guns have failed. The proper amount of shrinkage is not a fixed amount. It depends on the thickness of the rings, their position in the structure, and the modulus of elasticity of the material, and it is only by a due regard to these

elements of the problem that the advantages of the hoop system can be properly developed.

In illustration of this we refer to three diagrams of Sir Joseph Whitworth's 12-inch steel gun. The first, C_1, shows the strains, if the hoops are put in with no initial strain, that is to say, if each hoop is an exact fit to the one below it, which is Sir Joseph's present practice. The gun in this state is in the same condition under internal pressure as a homogeneous or solid gun of steel. The tensions with an initial pressure of 24 tons per square inch would be 28·18 tons and 2·3 tons per square inch at the inner and outer circumference respectively. The second diagram, C_2, would be the state of the strains, if the Woolwich rule of a uniform shrinkage of 1 in 1000 were adopted. The inner tube and the first hoop would never be out of compression, the second hoop would be strained to 8·44 tons and 3·85 tons, the third ring to 17·40 tons and 12·84 tons, and the fourth ring to 27·64 tons and 22·82 tons at the inner and outer circumferences respectively.

The third diagram, C_3, shows the gun as it would be strained if the initial shrinkages had been properly calculated and applied. For every hoop the tension of the inner circumference would be 10 tons per square inch, whilst that of the outer circumferences would be 1 ton compression for the tube, 4·11 tons, 6·51 tons, 7·72 tons, and 8·82 tons for the hoops respectively.

Thus it is seen that by a multiplication of hoops with initial strains properly applied the maximum strain is reduced from 28 tons to 10 tons per square inch. But on the other hand, by the Woolwich rule of a uniform shrinkage of 1 in 1000, some of the hoops would be always under compression, whilst others would be more or less strained, and the maximum would attain nearly the same as in the homogeneous gun—28 tons per square inch. Another remark must here be made. Referring to diagram C_3 it is seen that in the case of each hoop the strain decreases rapidly from the inner to the outer circumference. Thus in the first hoop the strain decreases from 10 tons to 4 tons, in the next from 10 tons to $6\frac{1}{2}$ tons, and so on. Now by greatly increasing the number of hoops and consequently decreasing the thickness of each, the strains on the outer circumference may be brought very nearly up to the same strain as the inner circumference, and this is what is attained by the use of *wire*. A coil of wire is but a very thin hoop, and if, instead of a hoop of $4\frac{1}{2}$ inches of steel, 36 coils of wire of $\frac{1}{8}$th inch had been used, the difference of strain between the inner and outer circumference of each coil would be inappreciable, and the whole thickness of the gun would have been uniformly strained, and the maximum strain would not have exceeded 6 tons per square inch, or if the wire were strained to 10 tons per square inch the thickness of the gun might be reduced from $22\frac{3}{4}$ to $13\frac{1}{2}$ inches.

But this is not all the advantage of the use of wire. Wire of small section is greatly stronger than the same material in mass. It is within the truth to say that steel which in mass might be safely strained to 15 tons per square inch, might in the form of wire be strained to 30 tons per square inch. Consequently the wire gun would be as safe under a strain of 20 tons as the hoops under 10 tons, and therefore the thickness of a wire gun of equivalent strength to that represented in diagram C_3 might be reduced to $6\frac{3}{4}$ inches instead of $22\frac{3}{4}$ inches.

From the preceding remarks and the diagram of Whitworth's 12-inch gun, it will be seen how very important is the question of the degree of shrinkage in built up guns. It is worth while to dwell a little longer upon this question, and to illustrate it we now give diagrams showing how the strength of a gun may be reduced by a small difference in the shrinking such as would be caused by a slight error in the dimensions of one of the hoops, due either to miscalculation, imperfect workmanship, or irregular contraction in cooling. The diagrams D_1 and D_2 represent the strains on the hoops of an 8-inch gun, built up of an inner tube and three concentric hoops of iron having an elastic limit of 12 tons per square inch. D_1 shows the strains when the gun is completed and free from internal pressure, on the hypothesis that the shrinkages are correctly calculated and accurately worked too. The tube and first hoop are in compression, the two outer rings in tension. D_2 represents the strain when subjected to internal pressure, so as to make the maximum strain 12 tons per square inch, and it is seen that all the hoops are equally strained up to the elastic limit. D_3 shows the strain in the same gun on the hypothesis that either from miscalculation or inaccurate workmanship the outer hoop has been made 1/500th of an inch too small, and when by internal pressure the maximum strain reaches 12 tons per square inch.

It is apparent at a glance what a great difference this error has made in the distribution of the strains. Without going into detail, it may be stated that the strength of the gun has been reduced 40 per cent. by the small error of 1/500th of an inch in one of the hoops. Accurate workmanship is, however, only one of the difficulties to be encountered in shrinking on hoops. Different qualities of iron shrink differently in cooling from the same temperature; moreover they do not shrink back in all cases to the size from which they were expanded, but to a somewhat smaller size. This depends on the temperature to which they have been heated. Moreover the shrinkage varies according to the number of times they have been heated. For instance, a wheel tier 7 feet diameter was heated red-hot, and cooled thirteen times in succession with the following results:—

1st time	it	contracted	$\frac{5}{8}$	in.	in length.
2nd	,,	,,	$\frac{11}{16}$	,,	,,
3rd	,,	,,	$\frac{7}{16}$	,,	,,
4th	,,	,,	$\frac{5}{8}$	,,	,,
5th	,,	,,	$\frac{3}{8}$	,,	,,
6th	,,	,,	$\frac{1}{4}$	,,	,,
7th	,,	,,	$\frac{1}{4}$	,,	,,
8th	,,	,,	$\frac{5}{8}$	,,	,,
9th	,,	,,	$\frac{1}{4}$	,,	,,
10th	,,	,,	$\frac{1}{4}$	,,	,,
11th	,,	,,	$\frac{5}{8}$	,,	,,
12th	,,	,,	$\frac{1}{4}$	,,	,,
13th	,,	,,	$\frac{1}{8}$	,,	,,

Thus altogether it contracted $5\frac{3}{8}$ inches from its original length of 22 inches.

It is clear therefore that however accurate the calculation and workmanship, there must be great difficulty in ensuring the exact amount of tension in this system of gun construction, and if guns are made without regard to calculation, without regard to the peculiar idiosyncracy of the iron, and without regard to the temperature from which the shrinking is made (and such is pretty much the case at Woolwich), it is no wonder that they split their tubes or shift their hoops in action. Many Woolwich guns have done this even under trial, and it is not improbable that in the late operations at Alexandria two of the guns of the *Alexandra* were injured in this way.

Another objection to this method of gunmaking is the possibility of latent defects in the hoops. It is impossible always to detect a flaw, even of considerable magnitude, in a hoop of iron or steel 10 to 18 inches thick such as are used in the large Woolwich guns, and such latent flaws may prove fatal to the gun even if in other respects it were properly constructed.

James A. Longridge

(*To be continued.*)

MR. FORBES' ZOOLOGICAL EXPEDITION UP THE NIGER

Mr. W. A. Forbes writes from Lokoja, on the Niger, at the confluence with the Binué (September 9) as follows:—I have been here on and off